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METHODS - ACQUISITION

OPTIMISATION OF STIMULI AND ACQUISITION TECHNIQUE FOR fMRI OF THE AUDITORY SYSTEM

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Purpose:

Advanced fMRI studies of the auditory system need a high performance audio system able to generate and transmit complex stereo sounds in a large frequency bandwidth with low distortion. Pneumatic sound systems delivered with MRI scanners are of poor quality mono channel. Thus complex paradigms will not be adequately transmitted through such systems. Also a flexible sound generator system is needed to easily adapt the paradigm to various fMRI acquisition techniques. Finally the strong noise generated by rapid gradient switching fMRI acquisition may cover the stimuli or generate unwanted BOLD response. Therefore a careful design and tuning of the sound generator and transmission system combined with an optimized acquisition technique is needed.

Materials and Methods:

The sound transmission system is made of a pneumatic headphone chosen to fit in the head coil with a high attenuation of the external noise. Each piece of the headphone is connected to a loudspeaker through a plastic tube of about 2 meters. In order to work in a strong magnetic field without any ferromagnetic attraction loudspeakers are based on a piezo-eletric technology. Each loudspeaker is inserted in an aluminum box with a little hole connected to the pneumatic headphone set. Each loudspeaker is connected through two coaxial cables, crossing the filter plate of the Faraday cage of the examination room, to a HiFi stereo amplifier and a 31-band (1/3 octave frequency each) stereo equalizer (ULTRACURVE BEHRINGER, Willich-Münchheide, FRG). A high performance equalizer is needed because the piezo-eletric loudspeaker is characterized by a narrow frequency bandwidth with strong resonance at some precise frequency prompt to saturation. The entire system was tested and tuned in an electro-acoustic laboratory. An artificial ear with a microphone at the place of the tympanum was used with a bi-channel analyzer and a frequency generator. Attenuation of different headphones in a 250 Hz to 8 kHz range was measured in order to choose the one with the highest attenuation values. The magnitude in frequency response (MFR) for each channel of the stereo system was measured in order to characterize the response of each piezo-electric loudspeaker inside the complete system without the equalizer. Then, by iteration, the equalizer was tuned for each loudspeaker in order to obtained the most constant MFR in the broadist possible bandwidth. To feed the system, basic complex sounds used to generate the paradigm are stored digitally in sampler and sequencer (MCP2000, AKAI, Japan) (up to 64 sounds of 5 sec each). This device is able to record and play sequences of basic sounds lasting for the entire fMRI experiment with a high temporal accuracy. Therefore a direct triggering of the MRI scanner is not needed even when the paradigm has to be synchronized with the fMRI acquisition. A computer using sound generation software (Macintosh, Sound designer II) generates basic complex sounds before to be recorded to the sequencer. As fMRI acquisition technique a high resolution single shot EPI gradient echo sequence is used (FA 90, TE 66, pixel size 1.8X1.8 mm, slice thickness 5mm, 16 slice 1,5 mm gap, acquisition time 3.95 sec). In order to avoid the overlap of stimuli and acquisition noise TR is set to 15 sec and the stimuli is presented during 5 sec before the acquisition This allows the bold effect to reach a maximum during the 4 sec of image acquisition. Then any cortical stimulation has enough time to decrease before the next acoustic stimuli. fMRI acquisition is organized in a triple epoch related study (for example movement-recognition-rest) of five acquisitions for each epoch, repeated six time (total acquisition time of 22 min).

Results:

Attenuation of external sounds by the headphone at 500 Hz is of -30 dB. Without the equalizer the frequency bandwidth of the system is 600 Hz to 4 kHz with variation of MFR up to 35 dB within this bandwidth. After tuning of the equalizer the bandwidth was of 300 Hz to 5 kHz with variation of MFR of less than 10 dB. Subjectively the addition of the equalizer is mandatory for complex task of sound recognition or localisation. Long TR fMRI sequence is able to guarantee the accurate analysis of the stimuli by the subject providing a strong BOLD response inside and outside the primary auditory cortex.

Conclusion:

"High fidelity" sound stimuli can be delivered to a subject during fMRI study without acquisition noise interference, allowing study of specialized area associated to the primary auditory cortex (1,2)

Reference:

1.

2. Maeder P., Meuli R., Adriani M. at al, Submitted to HBM 2000